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RESEARCH HIGHLIGHT



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Technical Series 04-108

GARAGE PERFORMANCE TESTING

INTRODUCTION

The indoor environment in houses has a profound impact on occupant's health and comfort. Research by the Canada Mortgage and Housing Corporation (CMHC), Health Canada, and Environment Canada have shown that attached garages can transfer automotive generated pollutants to the indoor air of houses, resulting in compromised indoor air quality. The amount of contaminant transfer and the effect of proposed solutions are highly variable depending on the airtightness performance of the house, garage, and their interface. The current research provides a basis for understanding the importance of attached garages as a source for indoor air quality problems, and identifies appropriate strategies for managing contaminant transfer in new and existing homes.

RESEARCH PROGRAM

The objectives of this research were to:

1. Establish the range and profile of airtightness in the garage-to-house interfaces in regions across Canada.
2. Determine the implications of garage-to-house air leakage on house indoor air quality.
3. Propose and test solutions for reducing contaminant transfer between garages and houses.

TEST MEASUREMENTS

A series of air tests were completed on forty-two homes located in Vancouver, Winnipeg and Saskatoon. These results were compared to previous tests completed on 25 houses located in Ottawa. The houses and garages were tested in accordance with the CGSB 149.10-M86, *Determination Of The Airtightness Of Building Envelopes By The Fan Depressurization Method* standard. Tests included:

1. House airtightness test,
2. Garage airtightness test, and
3. Balanced airtightness test¹.

Testing of remediation strategies was conducted in three Vancouver houses. The strategies tested include:

1. Air sealing of the garage-to-house interface,
2. Installation of a transfer grille in the garage, and
3. Installation of a garage exhaust fan.

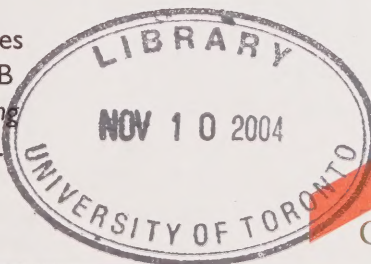
Each house was modelled using CONTAM airflow modelling² software to simulate airflow through the garage-to-house interface. CONTAM is a multi-zone indoor air quality and ventilation analysis computer program designed to model airflows: infiltration, exfiltration, and room-to-room airflows in building systems driven by mechanical means, wind pressures acting on the exterior of the building, and buoyancy effects induced by the indoor and outdoor air temperature difference.

FINDINGS

Airtightness Testing Results

Based on airtightness testing of 67 houses (42 in the current test, 25 in the Ottawa sample) with attached garages, it was found that:

- The average airtightness of homes is 8.4 AC/H, 3.7 AC/H, 3.1 AC/H and 4.8 AC/H for the Vancouver, Winnipeg, Saskatoon and Ottawa sample houses, respectively.



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¹ A balanced airtightness test was completed to obtain the garage-to-house interface leakage. To complete this test, a multi-point air test was taken with the garage and house at the same pressures. The result of the balanced test was subtracted from the house airtightness test.

² National Institute of Standards and Technology

- Garage air leakage rates, on average, are 37 AC/H, 18 AC/H, 17 AC/H and 47 AC/H for the Vancouver, Winnipeg, Saskatoon and Ottawa sample houses, respectively.
- The garage-to-house interface leakage is on average, 0.8 AC/H, 0.4 AC/H, 0.3 AC/H and 0.7 AC/H for the Vancouver, Winnipeg, Saskatoon and Ottawa sample houses, respectively.
- The house leakage through the garage-to-house interface accounts for 10% to 13% of the leakage in the sample houses.

Observations from the data include:

1. In general, the average garage house interface is consistent across sample houses and regions. However, a number of the Vancouver sample houses have garage-to house interface leakage areas that are significantly above the average.
2. The Vancouver houses with the largest interface leakage characteristics had furnaces located in a mechanical room accessed through the garage³. Primary leakage paths included:
 - Poor weatherstripping of the mechanical room doors,
 - Unintentional leakage of the return air ducts to furnaces causing depressurisation of the mechanical room, and resulting in entrainment of garage air and air transfer to the living space,
 - Excessive sized holes for penetrations between the mechanical room and living space.
3. Four houses (Va 02, Va 04, Va 08 and Va 10) had envelopes where more than 25% of the air leakage was occurring through the garage-to house interface (measured on the basis of ELA). No houses in the Winnipeg or Saskatoon sample had these elevated levels of leakage through the garage-to-house interface.

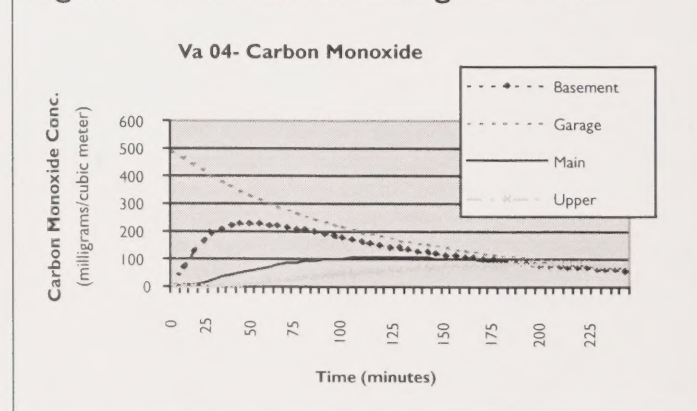
CONTAM Modeling Results

Modeling was completed for the 42 sample houses for carbon monoxide and benzene, using standard cold start and hot soak test procedures. The cold start tests represents combustion emissions from starting up a cold car in the garage in winter with the vehicle entry door open. The hot soak test represents the emissions given off by a hot engine as it cools over several hours while parked in the garage. A sample of the CONTAM model test results for Vancouver house

Va 08 is presented in Figure 1, depicting carbon monoxide concentration during the cold start test. A number of items were observed as part of the modeling exercise:

- Interior concentrations of carbon monoxide and benzene were correlated with the interface leakage area. In general, higher leakage rates correspond with higher indoor concentrations of pollutants.
- Interior concentrations of carbon monoxide and benzene were correlated to house and garage airtightness. As the houses and garages became tighter, the maximum concentrations of pollutants increase, as does their residence time.
- In cases where the interface leakage represented more than 25% of the total house leakage, the concentrations of carbon monoxide and benzene tended to increase significantly indoors. This situation occurred in a number of test homes located in Vancouver, including Va 02, Va 04, Va 08, and Va 10. For these houses, indoor levels of carbon monoxide exceeded the one hour 28.5 mg/m³ exposure limit recommended by Health Canada.
- All of the Vancouver homes with leaky interfaces had the mechanical rooms accessed through the garage. One house was a single family home (Va 02), while three were new row houses (Va 04, Va 08 and Va 10).

Figure 1: Contam Modelling For Va 08



Remedial Strategy Testing

Three remediation strategies were tested, including sealing of the interface area, installation of a transfer grille and installation of an exhaust fan. All three strategies were found to reduce peak concentration of pollutants in both the garages and the houses where

³ In general, locating mechanical rooms in the garage is considered poor practice. Test results from this study validate this assumption.

they were tested. Good garage-to-house air sealing is the preferred strategy for new houses, and may be effective for remedial work. Testing of the transfer grille was completed in a house where carbon monoxide exceeded Health Canada recommendations. Based on simulations, while peak concentrations of the pollutant were reduced as a result of installing the grille, the impact was not sufficient to eliminate the high indoor pollutant levels. Installation (and use) of an exhaust fan in the garage was found to successfully reduce contaminant entry. In cases where air sealing is not practical, installation of the fan in the garage is recommended.

IMPLICATIONS FOR THE HOUSING INDUSTRY

Characterization of the Garage to House Leakage Area

The 42 house sample results were combined with previous test results (Scanada, 1997) to develop a histogram of garage-to-house interface leakage. This information is summarised in Figure 2. Twenty-one of the 67-house sample have a garage-to-house leakage of 5% or less. In fact, four in the sample had 0% of the leakage occurring through the garage-to-house interface. In total 60 out of 67 (90%) of houses tested have a garage-to-house interface leakage less than 25%. However, the remaining 10% have interface leakage that exceeds 25%. If more than 25% of the house air leakage occurs through the garage, our simulations show that garage-based emissions could cause significant house indoor air quality problems.

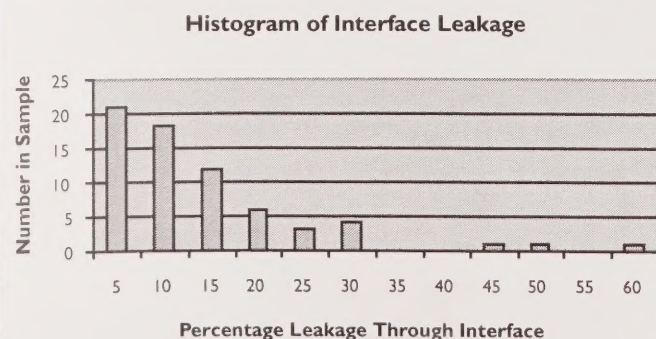
Based on the current analysis, the primary cause of pollutant transfer is poor air leakage control of the garage-to-house interface. Therefore improving the airtightness of that interface appears to be the preferred approach at the construction phase. In new homes, this may be accomplished through eliminating penetrations of the garage-to-house interface, and ensuring a good seal of any floors and any ducting located in the garage ceiling cavity. In particular, placing the mechanical room at this interface should be avoided. Eliminating the door between the garage and house may also be considered. Minimising electrical and mechanical penetrations should also be considered. For existing homes, homeowners may air seal the interface, including weather stripping of all doors, electrical penetrations and partitions. Living spaces over attached garages are particularly difficult to seal in the case of existing dwellings. Air may enter stud walls and pass through the wall top plate into the joist space from where it can get into living space above the garage. Leakage paths may include penetrations through the ceiling as well as penetrations through walls. While the penetrations through ceilings may be relatively easy to locate and seal, penetrations through walls may be more difficult to treat. To be effective, air sealing would require that ceiling drywall be removed around the perimeter of the garage and all joints in the wood framing be sealed with foam or sealant. For this situation, installing an exhaust fan that runs for 30 minutes is likely a more cost effective solution. Fans providing 25 L/s to 100 L/s capacity are acceptable. The fan could be controlled on a timer and interlocked with garage lights.

CONCLUSIONS

Based on the current analysis, the following conclusions are made:

1. Based on the airtightness testing completed on an additional 42 homes with attached garages, it was found that, on average, interface leakage accounts for approximately 10% to 13% of the total house leakage area. At these levels of garage-to-house transfer, carbon monoxide (CO) concentrations remain within acceptable exposure limits recommended by Health Canada. Note that cars with dirtier exhausts or idling periods longer than the 30 seconds will result in higher indoor conditions than those modeled.

Figure 2: Interface Air Leakage Histogram



2. If more than 25% of the house air leakage occurs through the garage, our simulations show that garage-based emissions could cause significant house indoor air quality problems. In total four of the 42 houses tested had interfaces where more than 25% of the house leakage occurred through the interface. Three of these houses were new row houses with the mechanical room located in the garage. The same four houses that were found to have loose garage-to-house interfaces were found to exceed recommended exposure limits for carbon monoxide on the basis of CONTAM simulations. Mechanical rooms with access through the garage should be discouraged due to high contaminant transfer potential in these dwellings.
3. Three remediation strategies were tested. All three strategies were found to reduce peak concentration of pollutants in both the garages and the houses where they were tested. Air sealing during construction is recommended to avoid pollutant entry. If a garage air infiltration problem is noticed in an existing house, air sealing should be the first line of defense. Even then, it may require the installation of a garage exhaust fan to lower pollutant entry to acceptable levels.

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Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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